(editor of the *Zeitschr. f. wissenschft. Insektenbiologie*) has undertaken to issue a more extensive work. It is significant of the increasing specialization in entomology that this new work is not the product of one author, but of eleven. It is divided into three parts: Volume I. is on the Anatomy, Embryology, Morphology, and Metamorphosis, and is prepared by Dr. C. Börner, Professor P. Deegener, Dr. J. Gross, and Dr. O. Prochnow. Volume II. will treat of the Habits, Distribution, Economic, and Experimental Entomology, and will be written by Dr. Schröder, Dr. K. Eckstein, Dr. O. Heineck, Dr. K. Holdhaus, Dr. L. Reh, and Dr. H. Rübsaamen. Volume III. will consider Paleoentomology, Phylogeny, and Systematics, and is to be prepared by Dr. A. Handlirsch. The portions now issued (three parts of Volume I.) are almost wholly by Dr. Deegener. Chapter I. is on the skin (including color, scales, skin-glands, scent-glands, wax-glands, etc.) with an appendix on the sound organs; Chapter II. treats the nervous system (especially the larger ganglia); Chapter III., the sense-organs, largely histological. In this chapter are various minor errors; the great family Capsidæ is not mentioned under Heteroptera as being without ocelli, the Panorpatæ are stated to have three ocelli, although on a previous page the genus *Boreus* is correctly stated to be without ocelli, and the various cases of ocelli in Coleoptera are unmentioned. The various sense-organs of unknown purpose (pseudocelli, abdominal organs of moths, post-antennal organs) are considered, as well as the supposed correlation or rather complemental development between the eyes and the antennæ. Chapter IV. considers the alimentary canal and its appendages (salivary glands, malpighian glands, anal glands) and is very complete, as Dr. Deegener is particularly interested in this matter. Chapter V. is on the respiratory organs, and is rather one-sided, most attention being given to respiration in aquatic insects and in parasites. Chapter VI. treats of the circulation, blood, heart, the specific heat of insects, fat-bodies, light-organs (rather briefly) and œnocytes. Chapter VII. relates to the endoskeleton and muscles. The muscular system of the imago of *Dystiscus* (as given by Bauer) is taken as typical, with but little comparison to other insects or larvæ. Only a brief summary is given of the endoskeleton, and brief treatment of muscular contraction, attachments of muscles, and muscular power of insects.

The most useful feature of the work is the long bibliographies at the end of each chapter. Although not by any means complete (American references often lacking) these lists furnish references that are difficult to secure but essential to any one studying these subjects. In fact, so useful is this new "Handbuch" that we hope a group of our entomologists will plan an American work on the same general lines.

NATHAN BANKS

TRIALS AND TROPISMS

I.

SOME years ago[1] I attempted an analysis of the facts grouped under the familiar but apparently confusing term "tropism theory." In the light of my experience I found myself seriously questioning the validity of a view that had just been published by Jennings in his well-known book, "The Behavior of the Lower Organisms." The issue was essentially this: whether tropisms are developed through selection from overproduced movements by means of the method of trial, or whether they are primary responses in the same sense that these overproduced movements are, and not, therefore, products of a process of selection as suggested.

Jennings soon found opportunity to reply to my objections as well as to those of other critics, notably Loeb and Parker. His reply, however, does not appear to have convinced them, for they have both taken issue since with his conception of the nature of tropic reactions. And though, up to the present, I have not thought it either necessary or desirable to add my own misgivings to a rapidly

[1] "The Method of Trial and the Tropism Hypothesis," SCIENCE, N. S., XXVI., pp. 313–23, September 6, 1907.

growing controversy, I too have failed to be convinced. Controversies fatten on misunderstandings. There is evidence that this one has been no exception to the rule. Some of it may be found in a recent book by Mast[2] and in a review and reply[3] that have since appeared. Accordingly, silence might seem to be the better part. Nevertheless, I am tempted to brave the possibility of further difficulty by accepting what seems to be a reasonable chance of focusing attention more sharply than before on the issue raised in my former paper.

It will be my endeavor, then, to show why the view that tropic reactions are developed through selection of overproduced or trial movements is unsatisfactory. And I shall attempt to do this by calling attention to certain relations between the structure and behavior of non-symmetrical and bilaterally symmetrical organisms that have heretofore met with much scantier consideration than, in my opinion, they deserve. Let me refer first of all to the behavior of the non-symmetrical flagellate *Euglena.*

II

Euglena, as is well known, is a non-symmetrical unicellular organism, with a single non-symmetrically placed photoreceptive region near the gullet, and swims in a spiral path by means of a flagellum, or, in the absence of the latter, assumes a crawling habit that is accompanied by a side-to-side oscillation suggesting the spiral swimming of the flagellated form.

I have been very much impressed by Mast's account of the orientation of the crawling *Euglena* to light. It appears that the organism, crawling in a path perpendicular to a beam of light, on entering the beam executes a turning movement toward the source of light; that this turning movement is accomplished by a series of sharp reactions, defined by a bending of the body away from the source of light; that each reaction follows an abrupt change in intensity of light falling on the photoreceptive region; and that these abrupt changes are connected with the oscillation of the organism from side to side, leading to an intermittent presentation of the photoreceptor to the light in a position effective for stimulation.

Few will deny that constant stimulation plays no obvious rôle here. But many, I am sure, will not fail to be impressed with certain elements of similarity in structure and behavior between *Euglena* and various bilaterally symmetrical organisms with one of a symmetrical pair of eyes blinded. And just here appears a point that has not been always clearly apprehended by the author of "Light and the Behavior of Organisms." Somehow Mast has obtained from my former paper the impression that I evidently consider "that orientation [in *Euglena*] is due to the local effect of unequal stimulation of symmetrically situated points on the body"—and yet do not "explain where the symmetrically located points which are subject to local stimulation are situated in *Euglena.*" I have looked carefully over my paper since this statement came to my notice, but have not been able to find any attempt to explain the orientation of *Euglena* on any such basis. That was perhaps a result to be expected, as I had not been conscious of an attempt so to explain the orientation of *Euglena* or any other non-symmetrical organism. Of the symmetrical points to which "it is evident" I refer, I frankly confess my ignorance. Nor do I feel any more hopeful than Mast himself of a successful issue to the most exhaustive search for them. Our reasons for this attitude of mind, however, do not coincide. For mine, the reader is referred to that suggestive resemblance between the structure and behavior of non-symmetrical organisms and symmetrical organisms non-symmetrically stimulated to which I would again call attention.

III

Let us imagine *Euglena* crawling horizontally along a definite axis of locomotion, directly toward a source of light. At successive

[2] "Light and the Behavior of Organisms," New York, 1911.

[3] Parker, *Jour. An. Beh.*, Vol. I., 1911, p. 461; and Mast, *ibid.*, II., p. 209.

moments it comes to lie in different positions, in all of which the single photoreceptor is at the same distance from the axis, and in some of which it occupies positions that—if the forward movement be for the moment disregarded—are symmetrically placed with reference to a plane passing through the axis of locomotion and perpendicular to the substratum. Let us now compare two such symmetrical images of *Euglena* with a bilaterally symmetrical animal, with paired eyes, moving directly toward a source of light. In *Euglena* the single photoreceptor is now on the left, now on the right of the plane of symmetry. In the other organisms, the two photoreceptors are permanently fixed, and one on each side of that plane.

Now *Euglena* swerves toward the light only when it is in such a position that the photoreceptor when on one side of the plane of symmetry receives light at an angle differing from that at which it receives light from the same source when occupying a symmetrical position on the other side of the plane. Just so, according to all varieties of the tropism theory with which I am acquainted, various bilateral organisms swerve toward the light when their eyes, symmetrically placed on either side of the median plane of the body, receive light from a single source at different angles. Expressed in another way, this means that the eyes under such conditions are subjected to different effective light intensities. The very mechanism, then, which has long been held by advocates of the tropism theory to account for the definite, errorless turning movements of bilateral heliotropic organisms toward or away from light, is the mechanism that Mast has shown to be accountable for the heliotropic orientation of the non-symmetrical *Euglena*. If this be the case, it seems evident that, whether or not the separate reactions of *Euglena* whenever its photoreceptor is effectively presented to the light are to be regarded as overproduced movements that may resemble trials, the definitely directive reactions of bilateral animals to light have not been developed by any process of selection based on such movements.

IV

It remains to consider the possibilities of such a mechanism for producing the delicately accurate heliotropic adjustments of some organisms; as well as the relation between pronounced shock reactions with no obvious relation to the direction of locomotion, and the definite errorless turning movements ordinarily referred to as tropic reactions.

Mast[4] says of the orientation of *Euglena* in light from two sources:

> When the light from the two glowers was equal and the *Euglenæ* positive, they moved in a general way toward a point midway between the glowers. But when it was unequal, they moved toward a point nearer the source from which the more intense light came. . . . This experiment is particularly striking if the glower on the track is gradually moved from a position in which the light intensity from it is much lower than that from the stationary glower to a position in which it is much higher. Under such conditions one can clearly see these organisms, especially the free swimming forms, gradually change their direction of motion through an angle of nearly 90°.

I gather from this description that changes in intensity are followed by reactions that vary with the degree of change. If this be true it may well account for the very slight variations which bilaterally symmetrical heliotropic organisms make from a straight course toward a source of light, and the precision with which such variations are corrected.

Further evidence of this sort is obtained from Fig. 13, p. 96, where, if the reactions are to be considered accurate in detail as drawn, it is seen that the orienting contractions of *Euglena* vary in magnitude as the path of the organism inclines more and more toward the source of light.

Similarly, Jennings[5] describes the avoiding reaction of the free swimming *Euglena* in the following terms:

> The *Euglenæ* are swimming about at random in a diffuse light, when a stronger light is allowed to fall upon them from one side. Thereupon the for-

[4] "Light and the Behavior of the Lower Organisms," p. 86.

[5] "Behavior of the Lower Organisms," p. 138.

ward movement becomes slower and the *Euglenæ* begin to swerve farther than usual toward the dorsal side. Thus the spiral path becomes wider and the anterior end swings about in a larger circle and is pointed successively in many different directions. In some part of its swinging in a circle the anterior end of course becomes directed more nearly toward the light; thereupon the amount of swinging decreases, so that the *Euglena* tends to retain a certain position so reached. In other parts of the swinging in a circle the anterior end becomes less exposed to the light; thereupon the swaying increases, so that the organism does not retain this position but swings to another. The result is that in its spiral course it successively swerves strongly toward the source of light, then slightly away from it, until by a continuation of this process the anterior end is directed toward the light. In this position it swims forward.

Figs. 91 and 92, p. 135, show variations in the severity of the reaction, the second figure representing but a very slight widening of the narrow spiral in which the organism has been swimming. Fig. 93, p. 139, represents the path of a *Euglena* executing a turn of 180° by a series of similar slight widenings of the spiral.

From such evidence it would seem that the motor reflexes of *Euglena* appear in varying degrees that shade more or less gradually into each other as the strength of stimulation varies. This admirably meets the requirements of a "tropism theory" that is expected to account for the gradual but definite and errorless turning movements executed by so many bilaterally symmetrical organisms in orienting themselves with respect to a source of light.

These considerations inclined me to the view that in bilaterally symmetrical organisms the shock reactions that have no obvious connection with orientation to a stimulus and are produced by *sudden changes in intensity* of light may occupy one end of a series at the other end of which are the very small reactions by means of which the tropic turning movement is achieved. In that case the difference in effect on orientation of these extreme cases would not indicate any fundamental difference in mechanisms governing them, but rather a pronounced difference in the magnitude of the responses to stimuli of different intensities.

Recently, however, my attention has been called to new evidence, shortly to be published by my friend, Dr. F. W. Bancroft, that in *Euglena* the mechanisms of the shock reaction and the tropic reaction are distinct. How general this observation may prove to be is not now certain. But in any case, the shock reaction can hardly be said to occupy the position of a prototype from which trialless heliotropic turning movements have been derived by any process of selection.

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January 9, 1913

AN AID TO STUDENTS

THE Academy of Natural Sciences of Philadelphia has published, as part of the aftermath of the brilliant centenary celebration of last year, an index to its publications from the first volume of the *Journal* issued in 1817 to the conclusion of the sixty-second volume of the *Proceedings* completed in 1911, making a total of eighty-three volumes. The portly index comprises 1,433 octavo pages and is divided into two sections. The first contains the titles of all the contributions to the series, arranged alphabetically under the names of the authors, and ranges from brief paragraph reports of the communications made verbally before the meetings of the academy to the classic quarto volume by Joseph Leidy on the extinct mammalian fauna of Dakota and Nebraska, and the beautiful monographs on the burial mounds of the south by Clarence B. Moore.

The second section is composed of an alphabetical arrangement, from *aalensis* to *Zythia,* of the names of every species, genus, and family described or referred to in the several volumes. It is estimated that there are about 124,600 such entries in the list and some idea of the labor involved in its preparation and arrangement may be had from the fact that the original entries under the letter P numbered 19,500, under S 16,650 and under T 10,300.